

[Document Name] Specification

[Title of the Invention]

Barley Lipoxygenase-1 Gene, Selection Method
for Barley, Materials for Malt alcoholic beverages
5 and Method for Production of Malt alcoholic beverages

[Claims]

[Claim 1]

A barley lipoxygenase-1 mutant gene, wherein
guanine at the splicing donor site (5'-GT-3') of the
10 5th intron of the barley lipoxygenase-1 gene is mutated
to a different base.

[Claim 2]

A barley lipoxygenase-1 mutant gene according
to claim 1, wherein the different base is adenine.

[Claim 3]

A selection method for barley lipoxygenase-1
deficient barley, comprising a step of distinguishing
the barley lipoxygenase-1 deficient barley by whether
or not the guanine at the splicing donor site of the
20 5th intron of the barley lipoxygenase-1 gene is mutated
to a different base.

[Claim 4]

A selection method for barley lipoxygenase-1
deficient barley according to claim 3, wherein the
25 different base is adenine.

[Claim 5]

A selection method for barley lipoxygenase-1 deficient barley according to claim 3 or 4, comprising a genomic DNA extraction step wherein genomic DNA is extracted from a barley sample,

5 a DNA fragment amplification step wherein a DNA fragment containing the splicing donor site of the 5th intron of the barley lipoxygenase-1 gene is amplified from the extracted genomic DNA, and

10 a DNA fragment detection step wherein the DNA fragment containing the splicing donor site of the 5th intron of the barley lipoxygenase-1 gene amplified in the DNA fragment amplification step is cleaved with a restriction enzyme, a DNA fragment having the prescribed number of bases is detected, and the barley

15 lipoxygenase-1 deficient barley is distinguished by whether or not the guanine at the splicing donor site is mutated to a different base.

[Claim 6]

A selection method for barley lipoxygenase-1 deficient barley according to claim 5, wherein the restriction enzyme used in the DNA fragment detection step is *Afa*I and/or *Rsa*I which recognize the nucleotide sequence 5'-GTAC-3'.

[Claim 7]

25 A material for malt alcoholic beverages, wherein the material is selected from a group consisting of

a seed, a malt, malt extract, barley decomposition product or processed barley derived only from barley having a barley lipoxygenase-1 mutant gene according to claim 1 or 2.

5 [Claim 8]

A material for malt alcoholic beverages, wherein the material is selected from a group consisting of a seed, a malt, malt extract, barley decomposition product or processed barley derived only from barley selected by a selection method according to any one of claims 3 to 6.

10 [Claim 9]

A method for production of malt alcoholic beverages characterized by using a material for malt alcoholic beverages according to claim 7 or 8.

15 [Detailed Description of the Invention]

20 [0001]

[Technical Field to which the Invention Pertains]

The present invention relates to a barley lipoxygenase-1 gene, a barley selection method, materials for malt alcoholic beverages and a method for production of malt alcoholic beverages.

25 [0002]

[Prior Art]

Barley lipoxygenase-1 (hereinafter, "LOX-1")

is an enzyme present in malt, which oxidizes malt-derived linoleic acid to 9-hydroperoxyoctadecadienoic acid during mashing for production of malt alcoholic beverages (non-patent document 1). 9-Hydroperoxyoctadecadienoic acid is further converted to trihydroxyoctadecenoic acid (THOD) by peroxygenase-like activity (non-patent document 2). It is known that THOD reduces beer foam head retention, imparts an astringent flavor and impairs smoothness of beer flavor (non-patent document 3 and 4), resulting in lower quality of malt alcoholic beverages. In addition, 9-hydroperoxyoctadecadienoic acid is converted to trans-2-nonenal which is the substance responsible for an unpleasant cardboard flavor in aged malt alcoholic beverages (non-patent document 5).

[0003]

As a strategy for inhibiting production of THOD and trans-2-nonenal in order to improve flavor stability and foam head retention of malt alcoholic beverages, there has been proposed a method of producing malt alcoholic beverages using malt with low LOX-1 activity (non-patent document 6).

[0004]

Douma et al. have induced mutation in barley by mutagenic (chemical) treatment to create an induced

mutated line exhibiting 9% of lower LOX-1 activity compared to controls, and have attempted to produce malt alcoholic beverages using such barley (patent document 1).

5 [0005]

Even when such barley is used, however, the reduced trans-2-nonenal concentration of the obtained malt alcoholic beverages is insufficient and flavor stability is not adequately improved. 10 Furthermore, absolutely no definite results have been achieved in terms of reducing THOD or improving foam head retention.

[0006]

[patent document 1]

15 WO02/053721

[0007]

[non-patent document 1]

Kobayashi, N. et al., J. Ferment. Bioeng., 76, 371-375, 1993

20 [0008]

[non-patent document 2]

Kuroda, H., et al., J. Biosci. Bioeng., 93, 73-77, 2002

[0009]

[non-patent document 3]

Kobayashi, N., J. Am. Soc. Brew. Chem. 60: 37-41.

2002

[0010]

[non-patent document 4]

Kaneda, H. et al., J. Biosci. Bioeng., 92,

5 221-226. 2001

[0011]

[non-patent document 5]

Yasui, Journal of the Brewing Society of Japan,
96:94-99 (2001)

10 [0012]

[non-patent document 6]

Drost, J. Am. Soc. Brew. Chem. 48:124-131 (1990)

[0013]

[Problem to be Solved by the Invention]

15 The present invention has been accomplished in
light of the aforementioned problems of the prior art,
and its object is to provide a barley LOX-1 gene which
is useful for production of malt alcoholic beverages
exhibiting improved flavor stability and foam head
20 retention without gene manipulation, a selection
method for LOX-1 deficient barley, materials for malt
alcoholic beverages derived from barley obtained by
the selection method, and a method for production of
malt alcoholic beverages using the materials for malt
25 alcoholic beverages.

[0014]

[Means for Solving the Problem]

As a result of much diligent research conducted with the aim of achieving the object described above, the present inventors have completed this invention 5 upon discovering a native barley variety which is completely deficient in LOX-1 activity, and identifying a novel LOX-1 mutant gene from the barley variety.

[0015]

10 Specifically, the LOX-1 mutant gene of the present invention is characterized in that the guanine at the splicing donor site (5'-GT-3') of the 5th intron of the known barley LOX-1 gene is mutated to a different base. The different base is preferably adenine.

15 [0016]

The selection method for barley LOX-1 deficient barley according to the invention is characterized by distinguishing the barley LOX-1 deficient barley by whether or not the guanine at the splicing donor 20 site of the 5th intron of the LOX-1 gene is mutated to a different base. The different base is preferably adenine.

[0017]

Also, the selection method for LOX-1 deficient 25 barley is characterized by comprising a genomic DNA extraction step wherein genomic DNA is extracted from

a barley sample; a DNA fragment amplification step wherein a DNA fragment containing the splicing donor site of the 5th intron of the LOX-1 gene is amplified from the extracted genomic DNA; and a DNA fragment detection step wherein the DNA fragment containing the splicing donor site of the 5th intron of the LOX-1 gene amplified in the DNA fragment amplification step is cleaved with a restriction enzyme, a DNA fragment having the prescribed number of bases is detected, and the barley LOX-1 deficient barley is distinguished by whether or not the guanine at the splicing donor site is mutated to a different base.

[0018]

The restriction enzyme used in the DNA fragment detection step is preferably AfaI and/or RsaI which recognize the nucleotide sequence 5'-GTAC-3'.

[0019]

According to the invention, the barley variety having the LOX-1 activity-deficient trait is distinguished based on the presence or absence of a mutation of guanine at the splicing donor site of the 5th intron of the LOX-1 gene.

[0020]

As a result, it is possible to easily distinguish the LOX-1 activity-deficient barley variety by analysis on the genetic level, without directly

measuring LOX-1 activity. Enzyme activity is influenced by individual growth stages, environment and other factors and is therefore difficult to measure precisely, but this method allows the LOX-1 activity-different barley variety to be distinguished in a different manner from enzyme measurement, and therefore independently of environmental and other factors. Moreover, while enzyme activity cannot be measured until the seeds have matured, DNA screening can identify the presence or absence of the activity-deficient trait at an early stage of growth since it is carried out before flowering, and is thus effective for continuous back-crossing.

15 [0021]

The material for malt alcoholic beverages of the invention is characterized by being a seed, a malt, malt extract, barley decomposition product or processed barley derived from barley having a LOX-1 mutant gene according to the invention.

20 [0022]

The material for malt alcoholic beverages of the invention is also characterized by being a seed, a malt, malt extract, barley decomposition product or processed barley derived from barley selected by a selection method for LOX-1 deficient barley according

to the invention.

[0023]

The method for production of malt alcoholic beverages of the invention is characterized by using 5 a material for malt alcoholic beverages according to the invention.

[0024]

According to the invention, it is possible to obtain malt alcoholic beverages with improved flavor 10 stability and foam head retention because LOX-1 is not present in the material, and therefore 9-hydroperoxyoctadecadienoic acid is not readily produced from linoleic acid and consequently THOD and trans-2-nonenal are also not readily produced in the 15 malt alcoholic beverage production method.

[0025]

[Embodiments of the Invention]

The present invention will now be explained in greater detail.

20 [0026]

To begin with, the LOX-1 mutant gene of the invention will be explained.

[0027]

25 The LOX-1 mutant gene of the invention is a novel gene discovered by the present inventors, and it is characterized in that the 60th base G of the 5th intron

of the known barley LOX-1 gene (SEQ ID NO: 1) is replaced by A (SEQ ID NO: 2). Since bases 60-61 of the 5th intron of the LOX-1 gene constitute the splicing donor site (5'-GT-3'), this base substitution produces an 5 aberration in LOX-1 splicing so that active LOX-1 cannot be expressed.

[0028]

10 The nucleotide sequence of the 5th intron region of the known LOX-1 gene is listed as SEQ ID NO: 1 in the Sequence Listing, and the nucleotide sequence of the portion of the LOX-1 mutant gene of the invention corresponding to the 5th intron region of the LOX-1 gene is listed as SEQ ID NO: 2.

[0029]

15 The selection method for LOX-1 deficient barley according to the invention will now be explained.

[0030]

20 The selection method for LOX-1 deficient barley according to the invention is characterized by distinguishing barley LOX-1 deficient barley based on whether or not the guanine at the splicing donor site of the 5th intron of the LOX-1 gene is mutated to a different base.

[0031]

25 The method for selecting LOX-1 deficient barley utilizing the aforementioned base mutation may be,

for example, a method of using a primer containing the aforementioned mutation site either at the 3' end of the primer sequence or within the primer sequence for amplification of DNA, detecting the base mutation 5 based on the presence of amplification or on the amplification efficiency and selecting the LOX-1 deficient barley, or a method of amplifying a DNA fragment containing the aforementioned mutation site, determining the nucleotide sequence to detect the base 10 mutation and selecting the LOX-1 deficient barley.

[0032]

There are no particular restrictions on the method of detecting the nucleotide sequence mutation so long as the method allows detection of DNA fragments, 15 but suitable methods to be employed include agarose gel electrophoresis and polyacrylamide gel electrophoresis. When the DNA mutation is to be detected based on the presence of amplification or on amplification efficiency, quantitative PCR such 20 as the TAQMAN method may be used instead of electrophoresis.

[0033]

The selection method for LOX-1 deficient barley of the present invention is characterized by 25 comprising, preferably,

a genomic DNA extraction step wherein genomic

DNA is extracted from a barley sample,
a DNA fragment amplification step wherein a DNA
fragment containing the splicing donor site of the
5th intron of the LOX-1 gene is amplified from the
5 extracted genomic DNA, and

10 a DNA fragment detection step wherein the DNA
fragment containing the splicing donor site of the
5th intron of the LOX-1 gene amplified in the DNA
fragment amplification step is cleaved with a
restriction enzyme, a DNA fragment having the
prescribed number of bases is detected, and the barley
LOX-1 deficient barley is distinguished by whether
or not the guanine at the splicing donor site is mutated
to a different base.

15 [0034]

The genomic DNA extraction step of the invention
will be explained first.

[0035]

20 There are no particular restrictions on the
method of extracting the genomic DNA from the barley
test sample, and any publicly known method may be
employed. Specifically, the extraction may be
carried out by, for example, the CTAB method (Murray
et al., 1980, Nucleic Acids Res. 8:4321-4325) or the
25 ethidium bromide method (Varadarajan and Prakash 1991,
Plant Mol. Biol. Rep. 9:6-12). The tissue used for

extraction of the genomic DNA is not limited to barley seeds, but may also be leaves, stems, roots or the like. For example, leaves may be utilized for selection of a lot of individuals in back-crossing 5 generations.

[0036]

The DNA fragment amplification step of the invention will now be explained.

[0037]

10 There are no particular restrictions on the method of amplifying the DNA fragment, and for example, the PCR (Polymerase Chain Reaction) method may be employed. The primers used for the PCR method are not particularly restricted in their nucleotide 15 sequences so long as they are of a region allowing amplification of a DNA fragment containing the splicing donor site of the 5th intron of the LOX-1 gene, and specifically, they are preferably 10-60 continuous bases and more preferably 15-30 continuous 20 bases of the LOX-1 gene. Generally, the nucleotide sequence of the primer will preferably have a GC content of 40-60%. Also, the difference in the Tm values of the two primers used for the PCR method is preferably zero, or very small. The primers 25 preferably do not form a secondary structure with each other.

[0038]

The DNA fragment detection step of the invention will now be explained.

[0039]

5 The LOX-1 mutant gene according to the invention has a different nucleotide sequence from the known LOX-1 as explained above, and therefore if a restriction enzyme which recognizes or cleaves the differing portion is used to cleave the amplification 10 product, a difference in the sizes of the obtained DNA fragments will be apparent. There are no particular limitations on the restriction enzyme used for the invention so long as it recognizes or cleaves the differing portion, but restriction enzymes AfaI 15 and/or RsaI, which have already been demonstrated to exhibit such activity, are preferred.

[0040]

In other words, since the LOX-1 mutant gene of the invention has the guanine at the splicing donor 20 site mutated to a different base, it lacks the cleavage site for restriction enzymes AfaI and RsaI (5'-GTAC-3': nucleotides 60-63 of the 5th intron) which are present in the known LOX-1 gene. As a result, 25 its cleavage pattern when the gene amplification product containing the cleavage site is cleaved with AfaI and/or RsaI will differ from that of the known

LOX-1 gene, thereby allowing identification of the LOX-1 mutant gene.

10 [0041]

5 The DNA fragment having the prescribed number of bases is not limited in its number of bases so long as it is a DNA fragment wherein the presence of the differing portion results in a difference in the size of the DNA fragment obtained by cleaving the amplification product with the restriction enzyme.

15 [0042]

The detection in this step is not particularly restricted so long as it is a method allowing detection of the DNA fragment cleaved by the restriction enzyme, and specifically, the detection may be accomplished by agarose gel electrophoresis or polyacrylamide gel electrophoresis, for example.

20 [0043]

The material for malt alcoholic beverages of the invention will now be explained.

25 [0044]

The material for malt alcoholic beverages of the invention is characterized by being a seed, a malt, malt extract, barley decomposition product or processed barley derived only from barley having the LOX-1 mutant gene according to the invention, and by being a seed, a malt, malt extract, barley

decomposition product or processed barley derived only from barley selected by a selection method for LOX-1 deficient barley according to the invention.

[0045]

5 Malt extract is the extract from malt, and as examples there may be mentioned the extract of sugar components or protein components from malt. Barley decomposition product is the product of decomposition of barley with enzymes or the like, and it includes
10 barley mash and the like. Processed barley refers to the milled barley used as the adjunct for beer, sparkling malt liquor and the like. Since the material for malt alcoholic beverages according to the invention contains no LOX-1, production of
15 9-hydroperoxyoctadecadienoic acid from linoleic acid does not readily occur, and consequently production of THOD and trans-2-nonenal also does not readily occur, during the malt alcoholic beverage production method; it is therefore possible to obtain malt alcoholic
20 beverages with improved flavor stability and foam head retention.

[0046]

Finally, the method for production of malt alcoholic beverages will now be explained.

25 [0047]

The method for production of malt alcoholic

beverages of the invention is characterized by using a material for malt alcoholic beverages according to the invention.

[0048]

5 The malting step according to the invention will be explained first.

[0049]

10 The malting step according to the invention is a malt obtaining step characterized by using LOX-1 deficient barley, and the method is not particularly restricted and may be a publicly known method. More specifically, for example, steeping to a steeping degree of 40-45% is followed by germination at 10-20°C for 3-6 days and kiln-drying to obtain malt.

15 [0050]

The mashing step according to the invention will now be explained.

[0051]

20 The mashing step according to the invention is a step of obtaining wort by mashing of the aforementioned malt. More specifically, it consists of the following four steps.

[0052]

25 The first step is a mashing step in which the malt-containing material is mixed with water, the obtained mixture is heated for mashing of the malt,

and the wort is obtained from the saccharified malt.

[0053]

The malt used for this step is preferably obtained by addition of water and air to barley for germination followed by drying to remove the radicles. The malt is the source of the necessary enzymes for production of wort, as well as the major starch source as the material for mashing. Also, kiln-dried germinated malt is used for production of the wort in order to impart the characteristic flavor and color of a malt alcoholic beverage. In addition to such malt, there may be added adjuncts such as LOX-1 deficient barley according to the invention and/or ordinary barley, corn starch, corn grits, rice, saccharides or the like.

[0054]

In the wort production step described above, malt extract, barley decomposition product or processed barley prepared from the LOX-1 deficient barley of the invention and/or ordinary barley is mixed with the mashing water, and the aforementioned adjuncts are added as necessary, to obtain the wort.

[0055]

The malt is mixed after addition to the mashing water. When adjuncts are also added, they may be also mixed in at this point. Saccharides may be added prior

to the boiling described hereunder. There are no particular restrictions on the mashing water, and water may be used which is suitable for the malt alcoholic beverage to be produced. The mashing may
5 be carried out basically under conventional conditions. After lautering of the malt mash obtained in this manner, materials which impart flavoring or bitterness such as hops or herbs are added and the mixture is boiled and then chilled to obtain
10 a chilled wort.

[0056]

The second step is a step of adding yeast to the chilled wort for fermentation to obtain intermediate products of a malt alcoholic beverage.

15 [0057]

The yeast used in this step may be any brewer's yeast for alcohol fermentation, which metabolizes sugars in wort obtained by malt mashing to produce alcohol and carbon dioxide gas, and specifically there
20 may be mentioned, for example, *Saccharomyces cerevisiae* and *Saccharomyces uvarum*.

[0058]

The fermentation is accomplished by cooling the wort obtained in the mashing step and adding the yeast thereto. The fermentation conditions may be basically the same as for conventional fermentation,
25

and for example, the fermentation temperature will ordinarily be no higher than 15°C and preferably 8-10°C, while the fermentation period is preferably 8-10 days.

[0059]

5 The third step is a storage step in which the intermediate products of the malt alcoholic beverage obtained in the fermentation step is stored.

[0060]

10 In this step, the fermentation solution which has completed alcoholic fermentation is transferred to a sealed tank and stored. The secondary fermentation is basically the same as conventional conditions, and for example, the storing temperature is preferably 0-2°C and the storing time is preferably 15 20-90 days. Storage of the fermented solution allows re-fermentation and maturation of the residual extract to occur.

[0061]

20 The fourth step is a filtering step in which the intermediate products of the malt alcoholic beverage obtained in the storage step is filtered to obtain a malt alcoholic beverage.

25 The filtering conditions are basically the same as conventional conditions, and for example, the filtering material used may be diatomaceous earth, PVPP (polyvinyl pyrrolidone), silica gel, cellulose

powder or the like, and the temperature may be 0 ± 1 °C.

[0062]

This procedure yields a malt alcoholic beverage.

5 The filtered malt alcoholic beverage is then tanked, barreled, bottled or canned for shipping to the market, either directly or after sterile filtration or heat treatment.

[0063]

10 The proportion of malt used for production of the barley alcoholic beverage is not particular restricted, and the alcoholic beverage may be any one produced using malt as the material. Specifically there may be mentioned, for example, beer and sparkling 15 malt liquor. Non-alcoholic beer and non-alcoholic sparkling malt liquor are also considered malt alcoholic beverages since the production method employed is similar to malt alcoholic beverages such as beer.

20 [0064]

Since the material according to the invention contains no LOX-1, production of 9-hydroperoxyoctadecadienoic acid from linoleic acid does not readily occur, and consequently production 25 of THOD and trans-2-nonenal is inhibited, during the malt alcoholic beverage production method, and it is

therefore possible to obtain malt alcoholic beverages with improved flavor stability and foam head retention.

[0065]

5 [Example]

The present invention will now be explained in greater detail through the following examples, with the understanding that these examples are in no way limitative on the invention.

10 [0066]

Search Test 1

(Search for LOX-1 deficient barley by LOX-1 enzyme activity measurement)

15 LOX-1 enzyme activity was measured by the method described below, and a search for LOX-1 deficient barley was conducted from barley gene resources.

[0067]

20 First, a crude enzyme solution was extracted from barley seeds by the following method. One mature barley seed was crushed with a hammer, and 500 μ L of extraction buffer (0.1 M sodium acetate buffer (pH 5.5)) was used for extraction with shaking at 4°C for 30 minutes. The obtained extract was centrifuged for 10 minutes at 15,000 rpm, and then the supernatant 25 was taken as a crude enzyme solution.

[0068]

Next, 5 μ L of substrate solution (40 mM linoleic acid, 1.0% (W/V) Tween20 aqueous solution) and 85 μ L of extraction buffer were added to 10 μ L of the crude enzyme solution and mixed therewith, and then reaction
5 was conducted at 24°C for 5 minutes. The reaction was terminated by adding and mixing 100 μ L of stop solution (80 mM 2,6-di-*t*-butyl-*p*-cresol, methanol solution). After allowing the reaction mixture to stand at -20°C for 30 minutes, it was centrifuged at
10 3000 rpm for 20 minutes and the supernatant was used in the following color developing reaction. A 200 μ L portion of a color developing solution (4 mM 2,6-di-*t*-butyl-*p*-cresol, 25 mM sulfuric acid, 0.25 mM ammonium iron(II) sulfate hexahydrate, 100 mM xylenol orange, 90% aqueous methanol) was added to
15 20 μ L of the obtained supernatant, and after standing for 30 minutes, the absorbance at 550 nm was measured. As a negative control, reaction was conducted in the same manner using the crude enzyme solution heat
20 treated at 100°C for 5 minutes for inactivation of LOX-1, while as a positive control there were used seeds of Kendall, a barley variety.

[0069]

As shown in Fig. 1, the search for gene resources
25 revealed no significant LOX-1 activity in SV73 (OUI003 stocked at Okayama University) seeds. Since SV73 is

a landrace, it is a spontaneous mutant rather than a mutagenized line.

[0070]

Verification Test 1

5 (Confirmation of lack of LOX-1 inhibiting activity in SV73 crude enzyme solutions)

SV73 crude enzyme solutions were examined for the presence or absence of LOX-1 inhibiting activity.

[0071]

10 SV73 crude enzyme solutions (10 μ L, 20 μ L, 50 μ L) were added to a crude enzyme solution exhibiting LOX-1 activity (positive control: PC) and the changes in LOX-1 activity were examined. The LOX-1 activity was unchanged with addition of the SV73 crude enzyme solution, and therefore no LOX-1 inhibiting activity was exhibited by the SV73 crude enzyme solutions (Fig. 2). This suggested that the cause of LOX-1 activity deficiency in SV73 was not due to a LOX activity-inhibiting substance.

15 20 [0072]

Verification Test 2

(Confirmation of LOX-1 protein expression level in SV73 seeds)

25 Anti-LOX-1 antibody was used to determine whether or not LOX-1 protein is expressed in SV73 seeds.

[0073]

An anti-LOX-1 antibody was prepared first. The LOX-1 protein used as the antigen was obtained by purifying LOX-1 protein expressed by *E. coli* (Kuroda et al. (2002) J. Bioscience and Bioengineering 93:73-77). The purified protein was used to immunize rabbits for production of LOX-1 antibody. This antibody recognizes both LOX-1 and LOX-2.

[0074]

Western blotting was then carried out in the following manner to examine LOX-1 protein expression in SV73 seeds. A 3 μ g portion of total soluble protein extracted from SV73 using 0.1 M sodium acetate buffer (pH 5.5) was fractionated by SDS-polyacrylamide gel electrophoresis (SDS-PAGE) and then blotted on a PVDF membrane (Millipore). The membrane was rinsed with TTBS (20 mM Tris-HCl (pH 7.5), 0.15 M sodium chloride, 0.05% (w/v) Tween20, 0.05% (w/v) sodium azide) and subsequently reacted with a LOX-1 antibody solution (1000-fold dilution/TTBS) for 30 minutes. The membrane was rinsed with TTBS three times for 5 minutes each time, after which reaction was conducted for 30 minutes with alkali phosphatase-labeled goat anti-rabbit IgG antibody solution (Santa Cruz Biotechnology, TTBS solution at 1000-fold dilution). After rinsing the membrane with TTBS for 5 min \times 2

and then with AP9.5 (10 mM Tris-HCl (pH 9.5), 0.1 M sodium chloride, 5 mM magnesium chloride) for 5 min x 1, reaction was conducted with alkali phosphatase substrate solution (1 mg/ml nitroblue tetrazolium, 0.5 mg/ml BCIP, AP9.5 solution) for color development. As a result, a dark band with a molecular weight of about 95 kD was obtained with the control variety (Kendall), while two very faint bands were detected at molecular weight regions of about 95 kD and about 57 kD with the SV73 seeds (Fig. 3A).

[0075]

The extraction sample was then subjected to isoelectric focusing (IEF, pI 3-9) using a PhastSystem (Amersham Pharmacia) and subjected to Western analysis in the same manner as above. As a result of analysis with SV73, a band was detected at the pI position of LOX-2, but no clear band was present at the pI position of LOX-1 (Fig. 3B). This suggested that the approximately 95 kD band appearing with the SV73 seed-extracted protein was LOX-2 protein.

[0076]

These results confirmed that SV73 seeds express virtually no authentic LOX-1 protein.

[0077]

25 Verification Test 3

(Analysis of SV73 seed LOX-1 RNA)

RT-PCR was carried out using as the template total RNA extracted from SV73 approximately 4-week ripened seeds and 3-day germinated seeds. The reaction was conducted using commercially available 5 kits (Roche Diagnostics, Perkin Elmer), according to the kit manuals. The primers were 5'-GGAGAGGAGGCCAAGAACAGATG-3' (SEQ ID NO: 3) and 5'-GGTTGCCGATGGCTTAGAT-3' (SEQ ID NO: 4), designed based on the published sequence (DNA Databank: 10 Accession No. L35931). After incubation at 94°C for 2 min, PCR was carried out with reaction at 94°C, 1 min, 60°C, 2 min and 72°C, 4 min, repeated 31 times, followed by extension reaction at 72°C, 7 min.

[0078]

15 Upon electrophoresis of the amplified DNA, amplification of an approximately 2.5 Kb band was detected for the RNA from the maturing and germinating seeds, although at a slightly lower amount than the control (Kendall variety) (Fig. 4). This indicated 20 that the LOX-1 gene was properly transcribed.

[0079]

Since the aforementioned results for the SV73 seeds indicated that (1) LOX-1 activity was not detected, (2) only a trace amount of antigen protein 25 reacting with the LOX-1 antibody was present, (3) the presence of a protein with a molecular weight of

approximately 57 kD was detected and (4) LOX-1 mRNA was detected, it was concluded that the mechanism for the deficiency of LOX-1 activity in SV73 was an aberration after transcription.

5 [0080]

Verification Test 4

(Structural analysis of SV73 LOX-1 gene intron regions)

In order to analyze the structure of the intron and exon regions of the LOX-1 gene, genomic DNA of a region comprising all of the exons was isolated. Total DNA from SV73 was used as the template. The primers (5'-CACGTCGCCGTCCGATCCATC-3' (SEQ ID NO: 5), 5'-GGTTGCCGATGGCTTAGAT-3' (SEQ ID NO: 4)) were 10 designed based on the reported sequence (DNA Databank: Accession Nos. U83904, L35931). The PCR was carried out with reaction at 94°C, 1 min, 65°C, 2 min and 72°C, 3 min, repeated 31 times, followed by extension 15 reaction at 72°C, 7 min. The obtained DNA fragment was cloned in pCR2.1 (pGLXABAL1) for use as the template for structural analysis. The structural analysis was carried out using an ABI sequencer, and the sequencing reaction was conducted by the dye 20 terminator method.

25 [0081]

SEQ ID NO: 1 of the Sequence Listing shows the

structure of the region of the reported nucleotide sequence of the LOX-1 gene (WO 02053721) containing the 5th intron. The splicing donor site is the nucleotide sequence 5'-GT-3' at positions 60-61.

5 [0082]

The nucleotide sequence of the corresponding region of SV73 determined from the analysis results is listed as SEQ ID NO: 2. Clearly in SV73, the guanine at position 60 in the splicing donor site is mutated 10 to adenine.

[0083]

Replacement of the 60th base of SEQ ID NO: 2 with adenine forms a new stop codon (the nucleotide sequence 5'-TGA-3' at positions 58-60 of SEQ ID NO: 2), and 15 therefore presumably translation of the LOX-1 protein ends at that point if the splicing site never changes to the upstream to the 5' end (Fig. 5).

[0084]

The exon region near the 5th intron is known to 20 be the active center of plant LOX (Shibata and Axelrod (1995), J. Lipid Mediators and Cell Signaling 12:213-228), and it is believed that the aforementioned splicing aberration has a major effect on the LOX-1 enzyme activity.

25 [0085]

Verification Test 5

(Analysis of splicing at 5th intron)

RT-PCR analysis was conducted in order to confirm that a splicing aberration had actually occurred in the 5th intron.

5 [0086]

Total RNA was extracted from germinating SV73 and Kendall, and a commercially available kit (Roche Diagnostics) was used for synthesis of cDNA to prepare template DNA. PCR was conducted using two different primers (5'-CCATCACGCAGGGCATCCTG-3' (SEQ ID NO: 6), 5'-GCGTTGATGAGCGTCTGCCG-3' (SEQ ID NO: 7)) designed to give an amplified fragment containing the 3rd intron (106 bp), 4th intron (132 bp) and 5th intron (79 bp) in genomic DNA sequence. The PCR was carried out with reaction at 94°C, 1 min, 65°C, 2 min and 72°C, 3 min, repeated 31 times, followed by extension reaction at 72°C, 7 min. Agarose gel electrophoresis of the amplified DNA fragments indicated that the SV73 amplified fragment was approximately 80 bp larger than the Kendall amplified fragment (Fig. 6A). An approximately 1.2 Kb fragment was amplified from the SV73 genomic DNA, suggesting that the results of the RT-PCR were the results for the expressed RNA.

20 [0087]

25 Next, in order to investigate in which of the introns the splicing aberration had occurred (the 3rd

intron (106 bp), 4th intron (132 bp) or 5th intron (79 bp)), the amplified fragment was digested at the restriction enzyme *Stu*I site present in the exon region between the 4th intron (132 bp) and 5th intron. As 5 a result, the DNA fragment containing the 5th intron had mobility roughly equivalent to that of one of the amplification fragments from genomic DNA, and therefore an aberration had obviously occurred in splicing of the 5th intron which had either prevented 10 splicing or had shifted the splicing site toward the 3' end (Fig. 6B). That is, clearly, the stop codon newly formed as shown in Fig. 5 had halted translation of the SV73 LOX-1 protein at that codon, resulting in loss of LOX-1 activity.

15 [0088]

Verification Test 6

(Mapping and selection of barley hybrid variety using 5th intron mutation)

In the reported LOX-1 nucleotide sequence, a 20 sequence containing the splicing donor site of the 5th intron (nucleotides 60-63 of SEQ ID NO: 1: 5'-GTAC-3') can be digested by restriction enzyme *Afa*I (or *Rsa*I) which recognizes the sequence GTAC. The LOX-1 deficient gene was mapped utilizing the fact 25 that a mutation is present in the sequence of this region in the SV73 line (nucleotides 60-63 of SEQ ID

NO: 2: 5'-ATAC-3') which prevents digestion by AfaI and/or RsaI (Fig. 5). DNA was extracted from the leaves of 144 individuals of a hybrid 2nd filial generation (F2) of a cross between Kendall and SV73 line, and PCR was conducted using two different primers (5'-CCATCACGCAGGGCATCCTG-3' (SEQ ID NO: 6), 5'-GCGTTGATGAGCGTCTGCCG-3' (SEQ ID NO: 7)) designed so that the amplified fragment would contain the AfaI site. The PCR was carried out with reaction at 94°C, 1 min, 65°C, 2 min and 72°C, 3 min, repeated 31 times, followed by extension reaction at 72°C, 7 min. Each of the amplified fragments was cleaved with AfaI and analyzed by 2.5% agarose gel electrophoresis (this will hereinafter be referred to as the "AfaI method"). As a result, it was possible to easily distinguish between the SV73, Kendall and hetero types (Fig. 7). In addition to the polymorphism examination by the AfaI method, polymorphism in each variety was also examined using a DNA marker (JBC970) near the LOXA gene locus of the barley 4H chromosome bearing the LOX-1 gene (Fig. 8).

[0089]

A mature seed of each F2 individual was used to examine the LOX activity of the seeds. For lines exhibiting no LOX activity, the activity was measured using several (4-7) seeds (Fig. 8).

[0090]

As a result of the AfaI method polymorphism examination of the F2 generation and LOX activity measurement of F3 seeds, segregation of the LOX-1 deficient trait of SV73 perfectly matched segregation of the AfaI method polymorphism. Thus, this series of genetic analyses clearly showed that the LOX-1 deficient gene of SV73 is at the LOXA gene locus.

[0091]

The results also demonstrated that using the AfaI method as an example of a barley selection method utilizing DNA mutation allows selection of LOX-1 deficient progeny lines at the early stage of the growth, eliminating the need to wait until the seeds have matured.

[0092]

Example 1

(AfaI polymorphism examination of other barley varieties)

General barley varieties/lines were used for AfaI polymorphism examination. A total of 32 varieties/lines were used: Mikamo Golden, Golden Melon, Haruna Nijo, Myogi Nijo, Sakitama Nijo, Wasedori Nijo, Agurimochi, Harupin Nijo, Ryofu, Hokuiku 33, Hokuiku 35, Prior, Schooner, Sloop, Lofty Nijo, Franklin, Betzes, Harrington, Manley, B1251,

CDC Kendall, CDC Stratus, CDC Copeland, Hanna, Merit, AC Metcalfe, TR145, Chariot, Stirling, Proctor, Koral and Heartland. As a result of AfaI method polymorphism examination, it was determined that the 5 tested varieties were not the SV73 type, but instead were digested at the restriction enzyme AfaI site containing the splicing donor site of the 5th intron (nucleotides 60-63 of SEQ ID NO: 1: 5'-GTAC-3') (Fig. 9). This indicated that these viable lines did not 10 possess a DNA mutation at the AfaI site (nucleotides 60-63 of SEQ ID NO: 1: 5'-GTAC-3'), and therefore that the AfaI method can be effectively utilized for selection of LOX-1 deficient genes among progeny lines.

15 [0093]

Example 2

(Gene resource search)

Worldwide gene resources (landrace) stocked at Okayama University were examined by the AfaI method. 20 As a result, five new lines (OUI001 (India), OUJ095 (Taiwan), OUJ695 (Taiwan), OUN345 (Nepal) and OUN347 (Nepal) stocked at Okayama University) were discovered which were not digested at the restriction enzyme AfaI site containing the splicing donor site 25 of the 5th intron (nucleotides 60-63 of SEQ ID NO: 1: 5'-GTAC-3') (Fig. 10).

[0094]

The LOX-1 activity of seeds of these lines was measured by the method described in Search Test 1. The activity measurement for OUN345 and OUN347 was 5 carried out by reaction for 5 minutes (Fig. 11A), while activity measurement for OUI001, OUJ095 and OUJ695 was with an extended reaction time of 90 minutes for clear identification of activity (Fig. 11B). As a result, no significant activity was found in any of 10 the lines (Fig. 11).

[0095]

This clearly demonstrated that SV37, OUI001 (India), OUJ095 (Taiwan), OUJ695 (Taiwan), OUN345 15 (Nepal) and OUN347 (Nepal) (SV73 type LOX-1 deficient barley) were LOX-1 deficient barley lines. Since all of the lines are landraces and not mutagenized lines, they represent spontaneous mutants for the LOX-1 gene.

[0096]

The results described above demonstrated that 20 the AfaI method, as an example of a barley selection method utilizing DNA mutation, is a technique allowing not only selection of LOX-1 deficient barley progeny lines, but also efficient selection of LOX-1 deficient barley from barley gene resources.

25 [0097]

Example 3

(Growth of barley for test brewing)

A barley variety, Taishomugi, was crossed with SV73, and the obtained first filial generation (F1) was self-pollinated to obtain an F2 generation. The 5 LOX-1 deficient trait was confirmed by the LOX-1 enzyme activity measuring method described in Example 1 and the AfaI method described in Example 7 above, and six LOX-1 deficient lines and ten LOX-1 retaining lines were provided as populations for the seed propagation 10 described below.

[0098]

Seed propagation was carried out for each line (population) using a uniform plot or greenhouse until F4 seeds were obtained. When the LOX-1 enzyme 15 activity of the F4 seeds was assayed, it was found that the respective LOX-1 activity traits of the F2 individuals were maintained, indicating that the LOX-1 deficient trait is stably passed on to progeny.

[0099]

The F4 seeds were used for the following malt production test and malt alcoholic beverage production test.

[0100]

Example 4

25 (Production of malt for test brewing)

A LOX-1 deficient barley F4 population (LOX-F4)

comprising barley seeds having no LOX-1 activity and a LOX activity-retaining barley F4 population (LOX+F4) from barley seeds with LOX-1, both derived from the Taishomugi x SV73 cross, were prepared and
5 used for malting.

[0101]

The malting was carried out using an Automatic Micromalting System (Phoenix Systems) under conditions with a steeping temperature of 16°C for
10 a total of 82 hours (5 hr WET/7 hr DRY cycle), germination at 15°C for 139 hours, and kiln-drying for 29 hours (55°C for 13.5 hrs, 65°C for 8 hrs, 75°C for 3.5 hrs, 83°C for 4 hrs).

[0102]

15 Example 5

(Analysis of malt and congress wort)

The malt was analyzed according to the EBC Standard Method (European Brewery Convention ed., Analytica EBC (4th Ed), 1987). As a result, no
20 significant difference was found between the malts using LOX-F4 and LOX+F4, demonstrating that they can be used for brewing of malt alcoholic beverages for the purpose of comparing the presence or absence of LOX-1 activity (Fig. 12).

25 [0103]

Next, 50 g of the malt was used to produce wort

by the Congress Method (European Brewery Convention ed., Analytica EBC (4th Ed), 1987), and the lipid oxidation in the congress wort was analyzed.

[0104]

5 First, the amount of trans-2-nonenal in the congress wort was measured by the following method. An 8 mL wort sample was placed in a vial, 3 g of NaCl was added, and the vial was capped. Next, a polydimethylsiloxane SPME fiber (Supelco, Inc.) was
10 inserted into the head space of the vial and the vial was incubated at 40°C for 15 minutes.

[0105]

15 The fiber was then inserted into a injection port of a gas chromatography/mass spectrometry equipped with a J&W DB-1 column as the capillary column (30 m x 0.25 mm, film thickness: 1 μ m). Helium was used as the carrier gas (1 mL/min) and oven conditions was from 60°C to 225°C (5°C/min), in select ion mode (m/z: 70). The quantitation was performed by the standard
20 addition method using trans-2-nonenal (Sigma) as standard sample.

[0106]

25 As a result, the trans-2-nonenal concentrations of the congress worts produced using LOX-F4 and LOX+F4 were 0.36 ppb and 3.85 ppb, respectively. Thus, it was demonstrated that production of wort using malt

according to the present invention allows production of trans-2-nonenal to be inhibited by as much as 1/10 or less of conventional malt.

[0107]

5 The nonenal potential of the congress wort was measured by the following method. First, the congress wort was boiled for 2 hours by the method of Drost et al. (Drost, B.W., vanden Berg, R., Freijee, F.J.M., van der Velde, E.G., and Hollemans, M., J. Am. Soc. Brew. Chem., 48, 124-131, 1990). The amount 10 of trans-2-nonenal in the sample was then measured by the trans-2-nonenal measuring method described above, and the nonenal potential of the congress wort was calculated.

15 [0108]

As a result, the nonenal potentials of the congress worts produced using LOX-F4 and LOX+F4 were 2.74 ppb and 11.9 ppb, respectively. Since the nonenal potential is known as an index of product aging 20 (Drost, B.W., et al., J. Am. Soc. Brew. Chem., 48, 124-131, 1990; Ueda et al. (2001) EBC-proceedings 55:p3 28th Congress), malt produced from barley according to the invention can be utilized for brewing 25 of malt beverages to significantly improve flavor stability of malt alcoholic beverages.

[0109]

5 The trans-2-nonenal concentrations and nonenal potentials of the congress worts produced using LOX-F4 are shown in Fig. 13 in comparison with those of congress worts produced using commercially available malt. As is clear by the results shown in Fig. 13, the worts of the present invention exhibited values that have not been achievable with conventional barley.

[0110]

10 These results demonstrated that utilizing barley according to the present invention allows production of malt with a superior level of quality not exhibited by conventional products.

[0111]

15 The THOD concentrations of the congress worts were measured by high performance liquid chromatography-mass spectrometry (HPLC-MS) analysis. The HPLC conditions were as follows. The flow rate of the mobile phase was 0.3 mL/min, using a mixed 20 solution of 0.5% acetic acid (Solution A) and acetonitrile (Solution B) as the mobile phase, with a linear gradient of Solution A: Solution B = 35: 65 (0 min) to Solution A: Solution B = 5: 95 (30 min). The column used was a Waters Asymmetry column 25 (No.106005; C18, 3.5 μ m: 2.1 x 150 mm), the column temperature was 50 °C, and a Model 1100 HPLC system

(Hewlett-Packard) was used for separation of 5 μ L of wort or beer sample. Mass analysis was performed using a Waters ZQ, with monitoring of mass 329 under ES ionization negative mode. The THOD standard solution used was a beer extract sample (Kobayashi, N., et al., J. Biosci. Bioeng., 90, 69-73, 2000).

5 [0112]

As a result, the THOD concentrations of the congress worts produced using LOX-F4 and LOX+F4 were 10 6.5 ppm and 14.7 ppm, respectively, thus demonstrating that production of wort using malt according to the present invention can inhibit the wort THOD concentration to 1/2 or below.

15 [0113]

As mentioned above, THOD is produced by conversion from linoleic acid by the action of malt LOX-1 and malt peroxygenase activity in the mashing step, but since malt peroxygenase activity is thought to be the rate-limiting step for THOD production 20 (Kuroda, H., et al., J. Biosci. Bioeng., 93, 73-77, 2002), it has not been clear to what degree reduced malt LOX-1 activity inhibits production of THOD. However, the results in the examples provided in the present specification have demonstrated that using 25 malt produced from barley seeds with no LOX-1 activity reduces THOD concentration in wort. Since THOD

survives to the final product without being metabolized by yeast (Kobayashi, N., et al., J. Inst. Brew., 106, 107-110 (2000)), the use of malt derived from barley according to the present invention can 5 clearly result in production of malt alcoholic beverages with good flavor quality and foam quality.

Example 6

(Test brewing of malt alcoholic beverages)

1. Production and analysis of wort

10 The LOX-F4 malt and LOX+F4 malt obtained in Example 11 above were mashed with a 50 L scale mashing apparatus according to the standard mashing methods for Haposhu, sparkling malt alcoholic beverage (malt content: 24%). The mashing conditions were as 15 follows.

[0114]

1.5 kg of each malt was mashed alone with 15 L of mashing water according to a diagram of 50°C for 20 min, 65°C for 30 min and 75°C for 3 min. After 20 mashing, wort lautering was carried out with a lauter tun. 35 L of lautered worts were obtained.

[0115]

Before boiling, the lautered wort was mixed with 5 kg of starch syrup (75% saccharides). 13 g of hop 25 pellets (bitterness unit: 87.0 BU (EBC)) was added into the wort. After boiling for 70 minutes, the

boiled wort was cooled to 10°C. The extract content of cooled worts were adjusted by water addition to 11.6-11.8%.

[0116]

5 The obtained worts were analyzed according to the EBC Standard Method (European Brewery Convention ed., Analytica EBC (4th Ed), 1987). The analysis values are shown in Table 1. As seen in Table 1, no distinct difference was found between LOX-F4 and 10 LOX+F4 with regard to parameters.

[0117]

[Table 1]

Table 1 analysis values of the worts

Variety	LOX+F4	LOX-F4
Specific gravity	1.0475	1.0467
Extract (%)	11.78	11.6
Real nonfermented extract (%)	3.45	3.38
Real attenuation (%)	70.7	70.9
Apparent nonfermented extract (%)	1.54	1.52
Apparent attenuation limit (%)	86.9	86.9
PH	5.88	5.93
Color (°EBC)	2.1	2.1
BU	31.2	27.3
Total nitrogen (mg/100 ml)	24	22
Polyphenol (mg/L)	44	48
FAN (mg/L)	46	51

15 [0118]

2. Production of malt alcoholic beverage (Happoshu, sparkling malt alcoholic beverage)

The wort obtained in 1. above was transferred

to a steam-sterilized 30 L scale cylindroconical tank, and then yeast was added to an initial concentration of 30 million cells/ml for main fermentation at 13°C. When the extract content in the fermentation liquid fell to 2.5%, it was transferred to a new similar tank for a storage step. The storage step was carried out at 13°C for the first 6 days and then at 0°C for 2 weeks thereafter.

5 [0119]

10 After finishing the storage step, fermentation liquid was supplied to a beer filtration and filling apparatus. Then it was filtered and filled into bottles.

3. Analysis of sparkling malt alcoholic beverage

15 The sparkling malt alcoholic beverage obtained in 2. above was analyzed as follows.

[0120]

20 Analysis according to the EBC Standard Method (European Brewery Convention ed., Analytica EBC (4th Ed), 1987) shows that no significant difference was found between LOX-F4 and LOX+F4 in terms of the general analysis parameters other than the lipid oxidation parameters (Table 2).

[0121]

[Table 2]

Table 2 analysis value of
the malt alcoholic beverage

Variety	LOX+F4	LOX-F4
Specific gravity	1.00562	1.00565
Original wort extract (%)	11.82	11.56
Real extract (%)	3.43	3.38
Real attenuation (%)	71	70.7
Apparent extract (%)	1.44	1.45
Apparent attenuation (%)	87.8	87.4
Alcohol (vol%)	5.5	5.35
Alcohol (w/w%)	4.33	4.21
PH	3.51	3.28
Gas pressure (20°C) kg/cm	2.35	2.55
Color (°EBC)	1.5	1.7
Total nitrogen (mg/100 ml)	16	19
BU	11.6	9.5
Polyphenol (mg/L)	45	43
FAN (mg/L)	10	12

5

[0122]

The foam head retention of the sparkling malt alcoholic beverage obtained in 2. above was analyzed by the following method.

[0123]

10 The foam head retention analysis was conducted by the NIBEM method. Upon analysis of the foam head retention using a Haffmans Foam Stability Tester (Table 3), the LOX-F4 barley clearly had higher foam head retention, with a NIBEM value of 21 points higher
15 than the LOX+F4 barley.

[0124]

Also, as a result of measuring the THOD

concentration by the method described in Example 12 above, the THOD content of LOX-F4 exhibited a reduction to less than half of that of LOX+F4.

[0125]

5 These results clearly demonstrated that the malt alcoholic beverage production method of the invention enable to produce the malt alcoholic beverage with reduced THOD content and improved foam retention.

[0126]

10 [Table 3]

Table 3 THOD and foam retention of the malt alcoholic beverages

Variety	LOX+F4	LOX-F4
NIBEM (corrected)	239	260
THOD (mg/L)	3.6	1.7

[0127]

15 The sparkling malt alcoholic beverage obtained in 2. above was then subjected to the following sensory test by 13 well-trained panelists for comparison of the flavor stability.

[0128]

20 First, the LOX-F4 and LOX+F4 malt alcoholic beverages were stored at 37°C for one week. They were then poured into cups at ordinary drinking temperature and provided for sensory test by panelists for evaluation of the off-flavor and total staleness on

a scale of 0-4 (with a higher value representing progressive aging) (Tables 4A, B).

[0129]

As a result, 10 of the 13 panelists assigned lower scores to LOX-F4 for off-flavor, and therefore LOX-F4 exhibited a lower score (average) than LOX+F4. The difference according to a paired t test was determined to be significant at the 5% probability (Table 4A).

[0130]

For the total staleness, 11 of the 13 panelists assigned lower scores to LOX-F4, and therefore LOX-F4 exhibited a lower score (average) than LOX+F4. The difference according to a paired t test was determined to be significant at the 5% probability level (Table 4B).

[0131]

The above sensory test and statistical analysis demonstrated that LOX-F4 had lower off-flavor and total staleness than LOX+F4.

[0132]

[Table 4]

Table 4A sensory test (off-flavor)

Off-flavor	LOX+F4	LOX-F4
Panelist 1	3	2
Panelist 2	1	2
Panelist 3	3	2
Panelist 4	2.5	2.5
Panelist 5	2	2
Panelist 6	2.5	2
Panelist 7	2.5	1.5
Panelist 8	2.5	1
Panelist 9	1	0.5
Panelist 10	2.5	2
Panelist 11	2	1.5
Panelist 12	2.5	2
Panelist 13	2	1.5
Average	2.2	1.7

Table 4B sensory test (total staleness)

Total staleness	LOX+F4	LOX-F4
Panelist 1	2.5	2
Panelist 2	1	2
Panelist 3	3	2
Panelist 4	3	2.5
Panelist 5	2.5	2
Panelist 6	2.5	2
Panelist 7	2.5	1.5
Panelist 8	2.5	1.5
Panelist 9	1	0.5
Panelist 10	2.5	2
Panelist 11	2	1.5
Panelist 12	2.5	2.5
Panelist 13	2	1.5
Average	2.3	1.8

5

[0133]

As a result of measuring the trans-2-nonenal content of the sparkling malt alcoholic beverage obtained in 2. above, LOX-F4 had a lower

trans-2-nonenal content than LOX+F4 before and after storage at 37°C for one week. The trans-2-nonenal content of LOX-F4 was reduced to approximately 1/3 compared to that of LOX+F4 after storage (Table 5).

5 [0134]

[Table 5]

Table 5 trans-2-nonenal content of
the malt alcoholic beverages

Variety	LOX+F4	LOX-F4
Before storage	0.02	0.014
After storage	0.35	0.12

(Unit: ppb)

10

[0135]

These results of the sensory test and results of analysis of the trans-2-nonenal content in the malt alcoholic beverages demonstrated that the malt 15 alcoholic beverage production method of the invention enable to produce the malt alcoholic beverages with improved flavor stability.

[0136]

Finally, the body and smoothness of the sparkling 20 malt alcoholic beverage obtained in 2. above were analyzed by sensory test and with a lipid membrane sensor.

[0137]

First, an sensory test was carried out by 13

well-trained panelists for comparison of the flavor quality. LOX-F4 and LOX+F4 sparkling malt alcoholic beverages were provided for sensory test, and the body and smoothness were evaluated on a scale of 0-4 (with 5 higher scores for fuller body and better smoothness) (Table 6).

[0138]

For body, no significant difference (5% probability level) was found between LOX-F4 and LOX+F4 10 (Table 6A).

[0139]

For smoothness, 8 of 13 panelists assigned higher scores to LOX-F4 (Table 6B). LOX-F4 had a higher (average) score than LOX+F4, and the difference 15 according to a paired t test was determined to be significant at the 5% probability level.

[0140]

These results demonstrated that brewing of malt alcoholic beverages using LOX-F4 can improve 20 smoothness without affecting body.

[0141]

[Table 6]

Table 6A sensory test (body)

Variety	LOX+F4	LOX-F4
Panelist 1	2	1
Panelist 2	3	2
Panelist 3	3	2.5
Panelist 4	3.5	3.5
Panelist 5	3	3
Panelist 6	2	2
Panelist 7	2	2
Panelist 8	3	2
Panelist 9	3	2
Panelist 10	2.5	2.5
Panelist 11	3	2
Panelist 12	2	3
Panelist 13	2	3
Average	2.6	2.3

Table 6B sensory test (Smoothness)

Variety	LOX+F4	LOX-F4
Panelist 1	1	2
Panelist 2	1	3
Panelist 3	1.5	3
Panelist 4	3	3
Panelist 5	1	1
Panelist 6	2	2
Panelist 7	2	3
Panelist 8	1.5	3
Panelist 9	1	2
Panelist 10	1.5	2
Panelist 11	2	3
Panelist 12	3	2
Panelist 13	3	2
Average	1.8	2.4

[0142]

The body and smoothness were also evaluated using a lipid membrane sensor, according to the method of Kaneda et al. (Kaneda, H. et al., J. Biosci. Bioeng.,

92, 221-226, 2001) (Table 7).

[0143]

The body was evaluated based on adsorption onto the lipid membrane, and the results showed no statistically significant difference (5% probability level) between adsorption with LOX-F4 and LOX+F4 (Table 7A).

[0144]

The smoothness was evaluated based on the duration of adsorption onto the lipid membrane (with a higher duration of adsorption indicating poorer smoothness), and LOX-F4 exhibited a residue of approximately 1/4 compared to LOX+F4, with a significant difference at a probability level of 1% (Table 7B).

[0145]

[Table 7]

Table 7A evaluation of body by
a lipid membrane sensor

	Adsorption	S.D.
LOX+F4	189	4
LOX-F4	187	3

(Unit: Hz. No significant difference
at 5% probability level)

Table 7B evaluation of smoothness by
a lipid membrane sensor

	Residue	S.D.
LOX+F4	12	3
LOX-F4	3	3

(Unit: Hz. Significant difference
at 1% probability level)

5

[0146]

No correlation has been hitherto found between barley LOX-1 activity and THOD production levels in mashing steps (Kobayashi, N. et al., (2000) J. Biosci. Bioeng. 90:69-73), and it has been unclear to what extent THOD production is reduced by inhibition of barley LOX-1. Moreover, it has not been possible in the prior art to predict whether smoothness can be enhanced as a result of such inhibition of barley LOX-1. However, the results of the sensory test and analysis of product body and smoothness using a lipid membrane sensor in the examples described in the present specification has demonstrated for the first time that barley containing the gene claimed herein can be utilized to enhance product smoothness without affecting product body.

[0147]

[Effects of the Invention]

It is possible to provide a LOX-1 mutant gene

which is useful for production of malt alcoholic beverages exhibiting improved flavor stability and foam head retention without gene manipulation, a selection method for LOX-1 deficient barley, 5 materials for malt alcoholic beverages derived from barley obtained by the selection method, and a method for production of malt alcoholic beverages using the materials for malt alcoholic beverages.

[0148]

10 [Sequence Listing]

SEQUENCE LISTING

<110> SAPPORO BREWERIES LTD.

15 <120> Barley lipoxygenase-1 gene, method of selecting barley variety, materials for malt alcoholic drink and manufacturing method of malt alcoholic drink

20 <130> 510-1378

<160> 7

<170> PatentIn version 3.1

25

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caacaactga tcgaaatatg 120

attgattgaa acgcmcaggc tgaacactca cgccgtgatg
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caacaactqa tcqaaatataq 120

5 attgattgaa acgcgcaggc tgaacactca cgcggtgatg
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20

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15

<400> 7

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[Brief Description of the Drawings]

[Fig. 1]

20 A graph showing the results for LOX-1 activity
in Search Test 1.

[Fig. 2]

A graph showing the results for LOX-1 inhibiting
activity in Verification Test 1.

25 [Fig. 3]

A pair of electrophoresis images showing the

results for Western analysis of barley seed LOX protein in Verification Test 2. Image A shows the results of Western analysis after SDS-PAGE, and B shows the results of Western analysis after IEF.

5 [Fig. 4]

An electrophoresis image showing the results for RT-PCR analysis of barley seed RNA in Verification Test 3.

[Fig. 5]

10 A diagram showing the structure of the splicing donor site of the 5th intron of the LOX-1 gene.

[Fig. 6]

15 A pair of electrophoresis images showing the results of analyzing splicing of the LOX-1 mutant gene in Verification Test 5. Image A is an electrophoresis image for amplified fragments containing the 3rd to 5th intron, and B is an electrophoresis image of the same fragments as A after digestion with StuI.

[Fig. 7]

20 An electrophoresis image showing DNA polymorphism in the hybrid 2nd filial generation for Kendall x SV73 in Verification Test 6.

[Fig. 8]

25 A table summarizing DNA polymorphism in the hybrid 2nd filial generation and LOX activity in the hybrid 3rd filial generation for Kendall x SV73 in

Verification Test 6.

[Fig. 9]

An electrophoresis image showing the results of analyzing a general barley variety/line by the AfaI method in Example 1.

5

[Fig. 10]

An electrophoresis image showing the results of analyzing LOX-1 deficient barley by the AfaI method in Example 2.

10 [Fig. 11]

A pair of graphs showing the results for LOX activity of LOX-1 deficient barley seeds in Example 2. Graph A shows the results at an enzyme reaction time of 5 minutes, and graph B shows the results at an enzyme reaction time of 90 minutes.

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[Fig. 12]

A table showing the results of malt analysis of seeds from the LOX+F4 population and LOX-F4 population in Example 5.

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[Fig. 13]

A dot graph showing trans-2-nonenal concentrations and nonenal potentials for wort in Example 5.